circuit board See **printed circuit board.**

circuit layout The calculation of the physical device dimensions required to produce the required electrical parameters. Vertical dimensions determine CVD and doping thickness specifications. Horizontal dimensions determine the wafer pattern dimensions and are the basis for a scaled drawing of the finished circuit (composite drawing).

class number Number of contaminant particles in a cubic foot of air.

clean room An area in which semiconductor device fabrication takes place. The cleanliness of the room is highly controlled in order to limit the number of contaminants to which the semiconductor is exposed.

clear field mask A mask on which the pattern is defined by the opaque areas.

cluster tool Several process stations or tools served by one loading–unloading chamber and wafer-transport system.

CMOS (complementary field-effect transistor) N- and P-channel MOS transistors on the same chip.

collector Along with the emitter and base, one of the three regions of the bipolar type of transistor.

collimated light Light in which the rays are parallel; used for gross visual inspection of surfaces.

composite drawing A scaled drawing of the finished circuit.

conductivity The ability of materials to conduct electricity (measured in siemens for conductance or ohms for resistance).

conductor A material which has low resistivity and high conductivity.

contact The regions of exposed silicon that are covered during the metallization process to provide electrical access to the devices.

contact aligner An aligner tool that clamps the wafer and mask into a tight contact before the resist exposure cycle.

contact mask The step at which holes are put into the wafer layers to allow the metal layer to reach down to the doped silicon substrate.

contamination A general term used to describe unwanted material that adversely affects the physical or electrical characteristics of a semiconductor wafer.

critical dimensions (CDs) The widths of the lines and spaces of critical circuit patterns as well as the area of contacts.

cryogenic pump A vacuum pump that can produce a vacuum to the 10^{-10} torr range, the same level as the vacuum of space. It does not require forepumps or cold traps and is faster than other types of vacuum pumps.

crystal A material in which the atoms are arranged in structured groups called unit cells.

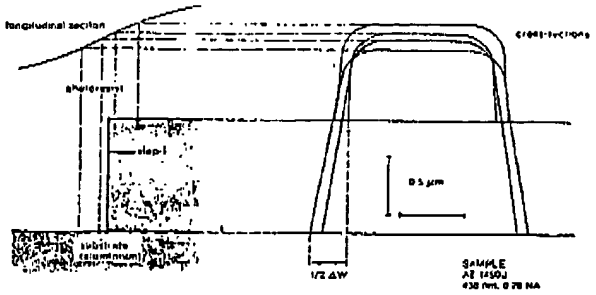

Fig. 32 Longitudinal section and cross sections of a photoresist line running across a one micron aluminum step. The resist profiles are simulated by SAMPLE. The nominal linewidth is 1.8 μm[52]. Reprinted with permission of SPIE.

On some microscopy-based inspection stations, all wafer handling and data processing functions have been automated. Only human vision remains as a non-automated aspect of the inspection procedure. That is, wafers are transported by belts or vacuum shuttle from an input cassette to a pre-aligner, then onto an inspection stage under the microscope (Fig. 31). Automatic handling allows the operator to concentrate on inspection, and to minimize the likelihood of airborne or human handling contamination. Inspection data is entered with a keypad, and many stations include host computer interfacing capabilities for processing and storing the data[63].

In more automated systems, the human operator is completely removed from the *defect inspection task*. That is, *in-process wafer inspection systems*, based on automatic image processing have been introduced. Defect detection is accomplished either by die-to-die or die-to-database comparison. Manufacturers of these systems claim defect detection sensitivities well into the sub-micron range. Such instruments, however, often have difficulty detecting particles on substrates that have surface granularity, or on wafers containing surface topography. In addition, for particles near the minimum-size detection limit, such machines can be prone to miss the presence of some particles, and signal the detection of others that may be non-existent.

The remainder of this section discusses linewidth measurement techniques used to verify that critical dimensions have been produced. In addition, procedures are described for monitoring the variation of linewidths produced in a production environment as a function of time. Such data can serve as a gauge for tracking the performance of a lithographic process line.

Linewidth Variation and Control

There are two aspects of feature sizes that must be controlled in the lithographic /etching process: a) the absolute size of a minimum feature, including linewidth, spacing, or contact dimensions (also referred to as a *critical dimension*, or CD); and b) the variations of the minimum feature sizes as they cross steps on the wafer surface. Linewidth (and spacing) measurements are regularly performed to determine the actual sizes of CDs at each masking level of a process. The variation of linewidths over steps are also monitored, and the causes of the variation were discussed in the section on *Resist Processing: Exposure*. These two aspects are mentioned together because there is also a tradeoff between absolute linewidth size and variation of the size over steps. That is, over-exposure and over-development can improve linewidth control, but at the expense of linewidth size. Figure 32 shows a SAMPLE simulation which calculates linewidth variation, ΔL, across a 0.5 μm step, as the line sizes vary with changing

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Electrical CD Metrology and Related Reference Materials

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I. INTRODUCTION

In the fabrication of integrated circuits, the steps of depositing a thin film of conducting material, patterning it photolithographically, and then etching it and stripping the remaining resist are repeated several times as required levels are created. On each occasion, the purpose is to pattern a film into a geometry that is consistent with the design of the circuit. The process control mission is to ensure that each respective set of process steps replicates patterning that meets engineering specifications. In most cases, a measure of this compliance is the closeness of the linewidths of features that are produced in the pattern to their intended "design," or "drawn" widths. Ideally, the linewidths of all features on each level would be sampled after the level is patterned, to provide an indication of whether or not the process is under adequate control. However, such a comprehensive metrology operation is neither economically nor technically feasible. Instead, the as-patterned linewidths of a limited selection of features that constitute a "test pattern," are measured. The test pattern is printed at the same time as the circuitry whose fabrication is being monitored, but at a separate location on the substrate that is reserved exclusively for process-control purposes. An example of a commonly used test pattern is shown in Figure 1 (1).

Usually, test patterns include features that have drawn linewidths matching the minimum of the features being printed in the circuit. These linewidths are typically referred to as the process's *critical dimensions* (CDs). It is the widths of the features in the test pattern that are measured by some means to determine if the respective sequence of patterning steps produces results that comply with engineering specifications. The presumption is that, if the CDs of the line features in the test pattern are found to be replicated within predefined limits, the CDs of the features replicated in the synthesis of the integrated circuit are replicated within those limits. The several common linewidth-metrology techniques in use today are electrical CD (ECD) (discussed in this chapter), scanning electron microscopy (SEM) CD, and scanning probe microscopy (SPM) CD.

metr- *pref. var. of* METRO-.
Met-ra-zol (mĕt′rə-zôl′, -zōl′). A trademark for pentylenetetrazol.
me·tre[1] (mē′tər) *n. Chiefly Brit. var. of* METER[1].
me·tre[2] (mē′tər) *n. Chiefly Brit. var. of* METER[2].
met·ric[1] (mĕt′rĭk) *adj.* [Fr. *métrique* < *mètre*, meter < Gk. *metron*, measure.] Designating, relating to, or using the metric system.
met·ric[2] (mĕt′rĭk) *n.* **1.** A standard of measurement. **2.** *Math.* A geometric function defined for a coordinate system such that the distance between any two points in that system may be determined from their coordinates.
met·ric[3] (mĕt′rĭk) *n.* [Gk. *metrikē (tekhnē)*, (the art) of meter.] Metrics.
met·ri·cal (mĕt′rĭ-kəl) *adj.* [Lat. *metricus* < Gk. *metrikos* < *metron*, meter.] **1.** Of, relating to, or composed in rhythmic meter. **2.** Of or relating to measurement. **—met′ri·cal·ly** *adv.*
met·ri·ca·tion (mĕt′rĭ-kā′shən) *n.* Conversion to the metric system of weights and measures: METRIFICATION.
metric centner *n.* A unit of mass equal to 100 kilograms.
metric hundredweight *n.* A unit of mass equal to 50 kilograms.
met·rics (mĕt′rĭks) *n. (sing. in number).* The branch of prosody dealing with measure and metrical structures.
-metrics *suff.* [< METRIC.] The application of statistics and mathematical analysis to a specified field of study <*econometrics*>
metric system *n.* A decimal system of weights and measures based on the meter as a unit length and the kilogram as a unit mass.
metric ton *n.* A unit of mass equal to 1,000 kilograms.
met·ri·fy (mĕt′rə-fī′) *vt.* & *vi.* **-fied, -fy·ing, -fies.** [OFr. *metrifier* < Med. Lat. *metrificare* : Lat. *metrum*, measure (< Gk. *metron*) + Lat. *facere*, to make.] **1.** To compose in or put into rhythmic meters. **2.** To convert to or adopt the metric system. **—met′ri·fi·ca′tion** *n.*
me·tri·tis (mə-trī′tĭs) *n.* Inflammation of the uterus.
me·tro (mĕt′rō) *n., pl.* **-tros.** [Fr., short for *(chemin de fer) métropolitain*, metropolitan (railway).] A subway system.
metro- or **metr-** *pref.* [NLat. < Gk. *mētro-* < *mētra*, uterus < *mētēr*, mother.] Uterus <*metritis*>
me·trol·o·gy (mĭ-trŏl′ə-jē) *n., pl.* **-gies.** [Fr. *métrologie* < Gk. *metrologia*, theory of ratios : *metron*, measure + *logos*, reckoning.] **1.** The science that deals with measurement. **2.** A system of measurement. **—met′ro·log′i·cal** (mĕt′rə-lŏj′ĭ-kəl) *adj.* **—met′ro·log′i·cal·ly** *adv.* **—me·trol′o·gist** *n.*
met·ro·nome (mĕt′rə-nōm′) *n.* [Gk. *metron*, measure + *nomos*, rule.] A device to mark time at a steady beat in adjustable intervals. **—met′ro·nom′ic** (-nŏm′ĭk) *adj.* **—met′ro·nom′i·cal·ly** *adv.*
me·tron·y·my (mĭ-trŏn′ə-mē, mĕ-) *also* **mat·ro·nym·ic** (măt′rə-nĭm′ĭk, mĕt′rə-) *adj.* [Gk. *mētēr*, mother + Gk. *onuma*, name + -IC.] Of, relating to, or derived from the name of one's mother or female ancestor. **—***n.* A metronymic name.
me·trop·o·lis (mə-trŏp′ə-lĭs) *n.* [LLat. < Gk. *mētropolis*, mother city : *mētēr*, mother + *polis*, city.] **1.** A major city. **2.** A city regarded as the center of a specific activity <*a great entertainment metropolis*> **3.** The chief see of a metropolitan bishop, esp. the main diocese of a specific ecclesiastical province. **4.** The mother city of an ancient Greek colony or state. **5.** *Zool.* A region in which a particular kind of organism lives and thrives.
met·ro·pol·i·tan (mĕt′rə-pŏl′ĭ-tən) *adj.* [ME < LLat. *metropolitanus* < Gk. *mētropolitēs*, citizen of a metropolis < *mētropolis*, mother city. **—**see METROPOLIS.] **1. a.** Of, relating to, or typical of a metropolis. **b.** Making up a metropolis. **2.** Relating to or comprising the home territory of a sovereign state. **3.** Of or relating to a metropolitan. **—***n.* **1. a.** An archbishop who has authority over bishops in the Roman Catholic and other episcopal churches. **b.** A bishop ranking next below the patriarch who serves as the head of an ecclesiastical province in the Eastern Orthodox Church. **2.** A resident of a metropolis, esp. one who displays big-city attitudes, characteristics, and values.
me·tror·rha·gi·a (mĕ′trə-rā′jē-ə, -jə) *n.* An abnormal uterine hemorrhage, esp. between menstrual flows. **—me′tror·rhag′ic** *adj.*
-metry *suff.* [ME *-metrie* < OFr. < Lat. *-metria* < Gk. < *metron*, measure.] Process or science of measuring <*isometry*>
met·tle (mĕt′l) *n.* [Alteration of METAL.] **1.** Inherent quality of character and temperament. **2.** Fortitude and courage : SPIRIT. **—on (one's) mettle.** Prepared to put one's spirit or courage to the test.
met·tle·some (mĕt′l-səm) *adj.* Full of courage : HIGH-SPIRITED.
mew[1] (myōō) *n.* [ME < OFr. *mue* < *muer*, to molt < Lat. *mutare*, to change.] **1.** A cage for hawks, esp. when molting. **2.** A secret place : HIDEAWAY. **3. mews.** A small street behind a residential street that contains small apartments. **—***v.* **mewed, mewing, mews.** **—***vt.* To confine in or as if in a cage. **—***vi.* To molt. **—**Used of a hawk.
mew[2] (myōō) *vi.* **mewed, mewing, mews.** [ME *mewen*.] To make the high-pitched, crying sound of a cat : MEOW. **—mew** *n.*
mew[3] (myōō) *n.* [ME < OE *mæw*.] A sea bird, *Larus canus*, one of the gulls found in northern Eurasia and western North America.
mew[4] (myōōl) *vt.* **mewled, mewling, mewls.** [Imit.] To cry weakly.
Mex·i·can (mĕk′sĭ-kən) *adj.* Of or relating to Mexico or to its inhabitants, their language, or their culture. **—***n.* A native or resident of Mexico.
Mexican hairless *n.* One of a breed of small dogs with a smooth hairless body except for tufts on the head and tail.

Mexican hairless
16–20 inches high at shoulder

Mexican Spanish *n.* The Spanish language as used in Mexico.
me·ze·re·on (mə-zĭr′ē-ən) *n.* [ME *mizerion* < Med. Lat. *mezereon* < Ar. *mdzaryūn*.] **1.** A native Eurasian shrub, *Daphne mezereum*, having fragrant lilac-purple flowers and small scarlet fruit. **2.** MEZEREUM 2.
me·ze·re·um (mə-zĭr′ē-əm) *n.* [Alteration of MEZEREON.] **1.** MEZEREON 1. **2.** The dried bark of certain shrubs of the genus *Daphne*, that was once used externally as a vesicant and internally for arthritis.
me·zu·zah *also* **me·zu·za** (mə-zōōz′ə) *n.* [Heb. *mezūzāh*, doorpost.] A small piece of parchment inscribed with the Biblical passages Deuteronomy 6:4–9 and 11:13–21 and marked with the word "Shaddai," a name of the Almighty, that is rolled up in a container and affixed to a door frame as a sign that a Jewish family lives within.
mez·za·nine (mĕz′ə-nēn′, mĕz′ə-nēn′) *n.* [Fr. < Ital. *mezzanino* < *mezzano*, middle < Lat. *medianus*, in the middle < *medius*, middle.] **1.** A partial story between two main stories of a building. **2.** The lowest balcony in a theater or the first few rows of that balcony.
mez·zo (mĕt′sō, mĕd′zō, mĕz′ō) *n., pl.* **-zos.** A mezzo-soprano.
mezzo forte (fôr′tā′) *adj.* & *adv.* [Ital.] *Mus.* Moderately loud.
mezzo pi·a·no (pē-ä′nō) *adj.* & *adv.* [Ital.] *Mus.* Moderately soft.
mez·zo-re·lie·vo (mĕt′sō-rĭ-lē′vō, -rēl-yĕ′vō, mĕd′-, mĕz′-) *n., pl.* **-vos.** [Ital. *mezzorilievo* : *mezzo*, half (< Lat. *medius*) + *rilievo*, relief < *rilevare*, to raise < Lat. *relevare*, to raise, relieve. **—**see RELIEVE.] Sculptural relief having modeled forms that project approx. halfway from the background.
mez·zo-so·pra·no (mĕt′sō-sō-prä′nō, -prə′nō, mĕd′-, mĕz′-) *n., pl.* **-os.** [Ital. ; *mezzo*, half (< Lat. *medius*) + *soprano*, soprano. **—**see SOPRANO.] **1. a.** A voice with a range between soprano and contralto. **b.** A vocal part for a voice with such a range. **2.** A woman with a mezzo-soprano voice.
mezzo-tint (mĕt′sō-tĭnt′, mĕd′-) *n.* [Ital. *mezzotinto* : *mezzo*, half (< Lat. *medius*) + *tinto*, tint < Lat. *tingere*, to dye.] **1.** A method of engraving a steel or copper plate by burnishing and scraping areas to produce effects of shadow and light. **2.** A print made from a plate engraved by mezzotint.
Mg *symbol for* MAGNESIUM.
mho (mō) *n., pl.* **mhos.** [Backward spelling of OHM.] A unit of conductance reciprocal to the ohm.
mi (mē) *n.* [Med. Lat. **—**see GAMUT.] *Mus.* The third tone of the diatonic scale in solfeggio.
MIA (ĕm′ī′ā′) *n.* [M(ISSING) I(N) A(CTION).] A serviceman who is reported missing following a combat mission and whose death can be neither confirmed nor denied.
Mi·am·i (mī-ăm′ē, -ăm′ə) *n., pl.* **Miami** *or* **-is.** A member of an Algonquian tribe of Indians once living in Ohio, Indiana, Illinois, and Wisconsin.
mi·as·ma (mī-ăz′mə, mē-) *n., pl.* **-mas** *or* **-mata** (-mə-tə) [Gk. < *miainein*, to pollute.] **1. a.** A poisonous atmosphere once believed to rise from swamps and putrid matter and cause disease. **b.** A thick vaporous atmosphere or emanation <*a miasma of cigar smoke*> **2.** A harmful influence or atmosphere <*a miasma of evil*> **—mi·as′mal, mi′as·mat′ic** (-măt′ĭk), **mi·as′mic** (-măz′mĭk) *adj.*
mi·ca (mī′kə) *n.* [NLat. < Lat., grain.] Any of a group of chemically and physically related mineral silicates, common in igneous and metamorphic rocks, that contain hydroxyl, alkali, and aluminum silicate groups and can be split into flexible sheets used in insulation. **—mi·ca′ceous** (-kā′shəs) *adj.*
Mi·cah (mī′kə) *n.* [Heb. *Mīkhāh*.] **—**See table at BIBLE.
mice (mīs) *n. pl. of* MOUSE.
mi·celle (mī-sĕl′) *n.* [NLat. *micella* < Lat. *mica*, grain.] **1.** A submicroscopic aggregation of molecules, as a droplet in a colloidal system. **2.** A colloidal organic particle found in coal. **3.** A coherent strand or structure in synthetic or natural fibers. **4.** A submicroscopic structural unit of protoplasm. **—mi·cel′lar** (mī-sĕl′ər) *adj.*

X. RELATED PROCEEDINGS APPENDIX

none

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